ESTABLISHING RECOVERY TARGETS FOR ILLINOIS PLANTS
A REPORT TO
THE ILLINOIS ENDANGERED SPECIES PROTECTION BOARD

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SUMMARY

We develop reclassification criteria for six federal threatened and Illinois-listed plant species based on their population sizes and distribution, life-history characteristics, biological information, population demography and trend analysis, ecological requirements, and habitat conditions. This information is used to conduct viability analyses and to develop indices projecting the viability of these species in Illinois. These estimates of population viability are used to develop recovery strategies and targets based on minimum numbers of viable populations in different Illinois Natural Divisions occupied by the species. Management and restoration can be used to increase population viability, and thus achieve species recovery targets. The viability analyses and projections, and recovery targets, are dynamic and can be altered as new information is gained.

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INTRODUCTION AND PROBLEM

The Illinois Endangered Species Protection Board has responsibility for determining the endangered or threatened status of Illinois vascular plants, and for establishing criteria for assessing population changes in these species that will allow their reclassification or de-listing. Recovery of endangered species must be goal-oriented and should include clearly defined success criteria in order to be effective (Noss & Cooperrider 1994, Pavlik 1996). General criteria such as size and number of populations, or expert testimony, have often been used to evaluate Illinois plant species' listing status (Sheviak 1981, Herkert 1991). However, these criteria are too simplistic to address the vast array of life-history and reproductive strategies (Weller 1994), habitat and disturbance process requirements (Pavlovic 1994), and natural temporal population fluctuations (*e.g.* Bowles *et al*. 1992) that characterize native plant species and affect their viability (Menges 1991). For example, viable populations of the self-incompatible *Asclepias meadii* and *Hymenoxys acaulis* var. *glabra* must contain genetically different individuals capable of cross-pollination and sexual reproduction (DeMauro 1993, 1994, Tecic *et al*. 1998, Bowles *et al*. 1998). Viable populations of the mononcarpic *Cirsium pitcheri* require seedling cohort establishment to offset mortality of adult plants after they flower, and seed dispersal is required to colonize shifting successional habitats in its shoreline dune system habitat (Bowles *et al*. 1993, McEachearn *et al*. 1994).

These differences among plant species indicate that tangible biologically-based criteria are needed to guide species reclassification, develop recovery planning and research strategies, and to serve as examples for other biologically and ecologically similar species.

OBJECTIVES

In this report, we prepare biologically- and habitat-based criteria to guide reclassification of six Illinois endangered or threatened plants that are either federal endangered or threatened (Table 1).

Table 1. Federal and Illinois status (Herkert 1991) of species chosen for establishing recovery targets

Species	Federal status	Illinois listing (& population status)
Asclepias meadii	Threatened	Endangered (4 populations, 7 restorations)
Cirsium pitcheri	Threatened	Threatened (extirpated, 1 restoration)
Dalea (*Petalostemum*) *foliosa*	Endangered	Endangered (4 populations, 1 restoration)
Hymenoxys acaulis var. *glabra*	Threatened	Endangered (extirpated; 3 restorations)
Lespedeza leptostachya	Threatened	Endangered (10 populations, 1 restoration)
Platanthera leucophaea	Threatened	Endangered (22 populations, 4 restorations)

Asclepias meadii is a perennial milkweed restricted to virgin prairie habitat. It formerly occurred throughout Illinois, but now occurs in a single railroad prairie in east-central Illinois, and in three southern Illinois glades. This genetically diverse species is self-incompatible; its remaining Illinois populations no longer produce seed and are vulnerable to stochastic extinction processes. Restoration of genetically diverse populations is underway at six northern Illinois sites and in southern Illinois. References: Chaplin *et al*. (1996), Bowles *et al*. (1998), Betz (1989), Bowles *et al*. (1993), Bowles *et al*. (1995), Bowles *et al*. (1998), Tecic *et al*. (1998).

Cirsium pitcheri is a monocarpic (once flowering) thistle restricted to blowout habitats along the Lake Michigan shoreline. Plants often occur as metapopulations and colonize early-successional blowouts. Seed production and seedling establishment are required to introduce new cohorts into populations to replace plants that have flowered and died. *Cirsium pitcheri* has been extirpated from Illinois and a restoration is underway in its only remaining Illinois habitat, at Illinois Beach State Park. References:

Pavlovic *et al*. (1993), Loveless & Hamrick (1988), Bowles *et al*. (1993), McEachern *et al*. (1994), Bowles & McBride (1996).

Dalea* (*Petalostemum*) *foliosa is a perennial legume that is restricted primarily to the DesPlaines River Valley, where four native populations and one restoration occupy wet dolomite prairie habitat. This species appears to be short-lived, has low genetic diversity, and its population maintenance may be highly dependent upon seedling recruitment from seed banks. Population restoration was initiated at Waterfall Glen, a DuPage County Forest Preserve. References: DeMauro & Bowles (1995), Baskin & Baskin (1973, 1979), Schwegman (1990).

Hymenoxys acaulis* var. *glabra is a perennial rhizomatous forb that formerly occupied dry-mesic gravel and dolomite prairie in the DesPlaines River Valley, and in Tazewell Co., Illinois. This species is self-incompatible, requiring crossing among different breeding types for seed production. It was extirpated from the last Illinois station, and restorations are underway at three sites. References: Demauro (1990, DeMauro (1993, 1994).

Lespedeza leptostachya is a disturbance-adapted legume of dry-gravel prairies in northern Illinois, where there are 11 native popopulations. This weak competitor is self-pollinating and has low genetic diversity. Its population sizes appear to be declining, but may fluctuate with rainfall. References: Smith *et al*. (1988), Smith (1987), Schwegman (1990).

Platanthera leucophaea is a short-lived perennial orchid that was formerly widespread across northern Illinois. It requires open prairie habitat, and 20 of the 22 native populations occur in the notheastern part of the state. Pollination requires hawkmoths, and soil fungi mycorhizzae are needed for seedling establishment. Flowering and population structure are enhanced by fire and high levels of rainfall. References: Bowles (1994), Bowles (1983), Sheviak & Bowles (1986), Bowles *et al*. (1992).

METHODS

Reclassification of endangered species to threatened status, or their de-listing, should use information demonstrating that they are no longer endangered or threatened with extirpation. To accomplish this, we compiled distributional, demographic, biological, ecological, and other habitat-based information for each study species, and combine it in a population viability analysis. The information comes from existing published literature and recovery plans, and from ongoing monitoring projects and restoration research. These estimates of population viability are then used to develop recovery strategies and targets based on minimum numbers of viable populations in different Illinois Natural Divisions across the species Illinois range. Management and restoration can be used to increase population viability, and thus achieve species recovery targets.

Landscape distribution and abundance of populations

Population persistence at the landscape level requires a minimum number of viable populations. In Illinois, the endangered category was initially applied to plants with no more than six populations (Sheviak 1981). A more specific approach would be to assure that a minimum number of these populations are protected, managed, and large enough to be viable, which is critical for their long term persistence. This allows development of minimum viable population criteria for reclassification from endangered to threatened, or for de-listing. In following sections, we describe methods for assessing the viability of populations. For plants with ranges extending across different Illinois Natural Divisions and sections

(Schwegman *et al*. 1973), the minimum number of viable populations should occur among different natural divisions to preserve or maintain as much of the species original distribution and genetic diversity as possible. For example, a species occurring in the Grand Prairie and Northeastern Morainal Natural Divisions would require a minimum of highly viable populations in each natural division. For some species, these requirements can be further divided among different habitats. *Platanthera leucophaea* occupies silt loam and sand prairie, and sedge meadow, in the Norhteastern Morainal Natural Division. For species restricted to single habitats in one natural division, metapopulation persistence may be considered as a requirement for reclassification. An example is *Cirsium pitcheri* restoration to unique habitat along the Lake Michigan shoreline.

Biological information

Understanding biological information relating to plant species life-history strategies is critical in assessing their viablity and projecting recovery needs. We compile life-history information for each species and apply it to population viability. For example, plant species life-spans arrange from annual to perennial, with intermediate biennial or monocarpic (once-flowering) strategies. Viable populations of short-lived species, such as *Cirsium pitcheri*, obviously require frequent recruitment of new seedling cohorts, while populations of long-lived perennials, such as *Asclepias meadii*, may persist with very infrequent reproduction and seedling recruitment. Plant species also have a vast array of breeding systems and reproductive strategies (Weller 1994), including, for example, self-pollinating annuals, rhizomatous perennials that spread vegetatively, or obligate outcrossing perennials with specific pollinator hosts. These differences may profoundly affect recovery strategies. Presence of pollinators would not be critical for recovery of self-pollinating species such as *Lespedeza leptostachya*, while native bees (*e.g. Bombus*, *Anthophora* sp.) appear necessary for cross-polination to occur among milkweeds but not for vegetative spread. In another case, *Platanthera leucophaea* requires pollination by hawkmoths (*Sphingidae*), and soil fungi mycorrhizae (*Rhizoctonia* species), for seedling establishment and persistence. As a result, recovery targets for these species should include insurance that populations of hawkmoth pollinators are present and protected, and that recovery sites support *Rhizoctonia* soil fungi. Potential for population recovery by seedling recruitment from soil seed banks also may be important for hard-seeded legumes such as *Dalea foliosa* or *Lespedeza leptostachya*, whose seeds can persist in soil, but not for *Asclepias meadii*, which has thin-coated seeds with short-term viability (Bowles *et al*. 1993).

Linkage between genetics, plant breeding systems and their reproductive biology provides key factors in determining whether plant populations can reproduce (Weller 1994). Factors such as distribution of genetic diversity within and among populations, effects of genetics on breeding system and reproductive potential (*e.g.* self-incompatibility and sensitivity to inbreeding), and pollinator requirements must be known to determine critical or weak reproductive stages for each plant species (0 1991, Menges 1991). For example, genetically diverse (polymorphic) species may be self-incompatible, which enforces out-crossing required to maintain high genetic diversity and avoid inbreeding depression. These mating systems are often controlled by the presence of self-incompatibility (SI) alleles at an SI locus. Viable populations would require an abundance of different SI alleles to allow successful seed production. Other genetically diverse species may be self-compatible, but still vulnerable to inbreeding, which is reduced by pollinator-enforced out-crossing. Species with low genetic diversity (monomorphic) are often self-compatible or self pollinating. For each species we addressed genetic factors that may critically affect population viability and subsequent recovery strategies, or, recommend investigations needed to identify such important factors. For example, *Asclepias meadii* and *Hymenoxys acaulis* var. *glabra* require crossing between genetically different individuals for seed production, and are also subject to inbreeding depression. As a result, recovery targets for these species may require genetic analysis of populations to insure that sufficient genetic diversity is present to insure successful outcrossing and seed production, and avoidance of inbreeding depression.

Ecological habitat requirements

Once plant genetics and breeding system issues are clarified, population assessment must consider ecological requirements, including habitat conditions and plant community structure, adaptations to natural disturbance processes, such as fire, or microsite-specialization, especially for seedling establishment (Pavlik 1994, Menges 1991, Fiedler & Laven 1996). Understanding related management needs are essential (Pavlovic 1994). For each species, we review habitat requirements and establish management criteria needed to assure habitat persistence. For example, prairie species such as *Asclepias meadii* and *Platanthera leucophaea* require prescribed burning to maintain their prairie habitat. Fire also promotes flowering in these species, and enhances seedling establishment of *A. meadii* (Bowles *et al*. 1998). *Cirsium pitcheri* is adapted to natural shoreline disturbances that maintain its mid-successional habitat on foredunes, but it is vulnerable to high intensity disturbances that eliminate foredunes and erode beaches (McEachern *et al*. 1994) .

Demographic information

Recovery of endangered species requires not only that populations exist in protected habitats, but also that these populations can maintain themselves for long periods of time. Different plant species often have different life-history strategies for population maintenance. For example, monocarpic (once flowering) species, such as *Cirsium pitcheri*, rely upon recurring seedling cohort establishment to replace adult cohorts that are lost by post-flowering mortality. In contrast, short-term population maintenance of polycarpic (multiple flowering) perennial species may rely more on adult longevity (*e.g. Asclepias meadii*) or by rhizomatous spread (*e.g. Hymenoxys acaulis* var. *glabra*). However, long term population maintenance will also require seedling establishment. Demographic monitoring is used to analyze the stability of these populations. It provides trend analysis data needed to 1) determine whether populations are growing, stable, or declining (Menges 1986, 1990, 1991, 1996); and 2) analyze factors that limit population maintenance and growth (Menges 1990, Pavlik 1994).

Trend analysis provides an early warning system that helps determine which populations are in trouble before they actually decline or whether current management practices are promoting population viability. Demographic trend analysis can estimate population viability more accurately than annual census counts of either the total number of individuals, or the numbers of flowering individuals, in a fraction of the time (2-4 years versus 5-15 years). Demographic monitoring follows survivorship, growth and fecundity of individual plants in a population over time. Trend analysis uses demographic information to determine whether a population has the potential for growth, stability or decline in the near future (Menges 1996), allowing identification of life-history stages that have the greatest effect on population growth and analysis of biological and ecological causes of variation in these stages (Pavlik 1994, Schemske et al. 1994). Census counts alone do not allow projection of population growth (Pavlik 1994). For each species we assess methods for determining population viability, including individual factors that may affect survival at various growth stages or size classes.

Integrated Trend Analysis

Demographic trend analysis can be integrated or non-integrated. An integrated approach combines information from all life-history stages to determine population dynamics and is preferred because it can determine population growth rate. For plants it is also preferable to use a matrix projection model in which probability of moving from one stage to the next can be calculated (Caswell 1989; Gotelli 1998), rather than an age-based life table analysis which is age-based. Many perennial plants alternate between flowering and nonflowering stages and exhibit periodic dormancy, and transitions between stages depend on competition and growing season rainfall (for example *Asclepias meadii*, Bowles *et al*. 1998). In plant demographic matrix models, individuals are grouped into stage classes in a matrix containing transition probabilities between stages from one year to the next (Menges 1986). A simple matrix can be represented by *Dalea foliosa*, Leafy Prairie Clover, which has four stages: seedling, vegetative, dormant, and flowering (Table 2).

Table 2. Generalized stage-based projection matrix for *Dalea foliosa*, Leafy Prairie Clover.

	Stage in first year			
Stage next year	**Seedling**	**Vegetative Plant**	**Dormant**	**Flowering Plant**
Seedling				F_4
Vegetative Plant	G_{12}	P_{22}	G_{32}	G_{42}
Dormant		G_{23}	P_{33}	G_{43}
Flowering Plant	G_{14}	G_{24}	G_{34}	P_{44}
Mortality	$1 - G_{12} - G_{14}$	$1 - P_{22} - G_{23} - G_{24}$	$1 - G_{32} - P_{33} - G_{34}$	$1 - G_{42} - G_{43} - P_{44}$

In the projection matrix, the stage that a particular individual is in the first year appears across the top of the table and stages that the individual will become the next year are found on the left side of the table. The letters (P, G, F) in the body of the table represent the probabilities that an individual in a particular stage in the first year will be in a particular stage the next year. Transitions labeled with a "G" indicate growth from one stage to the next. Subscripts indicate stages involved and direction of the transition, with the first subscript representing the stage in the first year and the second subscript representing the stage the next year. For example, G_{12} represents the transition from stage 1 (seedling) in the first year to stage 2 (vegetative plant) the next year. Transitions labeled "P" indicate the probability of remaining in that stage. For example, P_{44} represents the probability that a flowering plant (stage 4) in the first year will also be a flowering plant (stage 4) the next year. The letter "F" represents fecundity, or number of seeds produced per flowering plant. All individuals in a stage in the first year are accounted for in the next year. For example, a seedling in the first year has a certain probability (G_{12}) of becoming a vegetative plant the next year, or of becoming a flowering plant (G_{14}), or of dying ($1 - G_{12} - G_{14}$). The same stages are represented in the generalized demographic model (Figure 1) in which life history stages are represented graphically by circles. The arrows represent transitions from one stage to the other. For example, the arrow labeled G_{12} represents the transition from seedling to vegetative plant. Only logical transitions are illustrated: there is no arrow from vegetative plant to seedling since vegetative plants do not develop into seedlings.

The matrix can be analyzed using computer software, such as RAMAS (Ferson, 1994) or POPPROJ (Menges, 1997) to determine the finite growth rate of the population, which is represented by lambda (λ). For growing populations $\lambda > 1$, declining populations have $\lambda < 1$, and $\lambda = 1$ for stable populations.

Non-integrated Trend Analysis

When data on all transition stages are unavailable, non-integrated trend analysis uses parallel interpretation of data on survivorship, fecundity and establishment to determine whether a population has the potential for stability (Pavlik 1994). Examples of demographic parameters which can be used for perennial plants are presented in Table 3. As many of these types of parameters as possible can be used to assess population stability.

Table 3. Demographic parameters that can be used to determine whether a population of perennial plants has the potential for stability.

	a population should be stable if
1	the number of established juveniles and/or seedlings is greater than the number of established reproductive individuals
2	seed production per individual of an endangered taxon equals or exceeds that of a non-endangered relative with similar life-form
3	the half life of established reproductive plants exceeds the frequency of establishment
4	the seed/ovule ratio (S/O) is approximately 0.5 or similar to a non-endangered relative with similar life-form.

Figure 1. Generalized stage-based population dynamics model for leafy prairie clover (*Dalea foliosa*) presented as a graphical network. Circles represent stages and arrows represent possible transitions between stages.

Non-integrated trend analysis can be illustrated using the Illinois threatened savanna blazing star (*Liatris scariosa* (L.) Willd. var. *nieuwlandii* Lunell, Asteraceae), a shade adapted savanna perennial that appears vulnerable to competition from prairie grasses, such as big bluestem (*Andropogon gerardii*). For example, at Hickory Creek Barrens in Will County, Illinois, densities of this blazing star were lower in plots that contained high big bluestem cover, and were higher in low bluestem cover plots. Non-integrated trend analysis indicates that the blazing star population is potentially growing or stable on low big bluestem cover sites, but less stable and even potentially declining in dense big bluestem cover sites. The potential for population growth in both sites is indicated by an increase in total plants as well as by fewer numbers of established flowering plants than recruited seedlings (Table 4). However, recruitment and flowering plant survivorship are significantly lower in the dense big bluestem sites. These results predict that the expected increase in big bluestem cover at Hickory Creek Barrens will result in reduction of the savanna blazing star population.

Table 4. Demographic differences between dense and low Big Bluestem (*Andropogon gerardii*) cover sites for Savanna Blazingstar (*Liatris scariosa* var. *nieuwlandii*) at Hickory Creek Barrens, Will County, Illinois. Data are means (±se) over 40 plots and indicated number of years. Probabilities in bold indicate significant (≤ **.05**) differences between dense and low Big Bluestem cover sites.

Demographic characteristic	**Number of Years**	**Dense Big Bluestem Cover**	**Low Big Bluestem Cover**	**Probability that means are not different**
density (total # plants /m²)	3	6.7 ± 1.0	15.5 ± 1.6	**0.0039**
density change	3	increase	increase	
survivorship (%) - seedling	1	76.7 ± 6.7	81.6 ± 3.6	0.2189
survivorship (%) - nonflowering plant	1	89.2 ± 4.8	75.9 ± 5.9	0.1711
survivorship (%) - flowering plant	1	41.7 ± 13.9	83.3 ± 9.4	**0.0425**
recruitment (seedlings /m²)	2	3.2 ± 0.6	8.2 ± 1.1	**0.0013**
flowering plant density (#/m²)	3	0.47 ± 0.12	0.91 ± 0.15	0.063
flowering frequency (%)	3	3.7 ± 1.0	5.6 ± 0.9	0.1491
seed predation (%)	1	14.2 ± 3.7	33.2 ± 5.0	N/A
corm predation (%)	1	48.3 ± 14.1	12.5 ± 8.9	**0.0388**
flowering stalk cut off (%)	1	0 ± 0	30.8 ± 12.7	**0.04**

Where possible integrated trend analysis should be used for population viability analysis. However, where data are insufficient we use non-integrated trend analysis. For example, location of the cryptic seedling stages is very difficult for *Platanthera leucophaea*, the eastern prairie fringed orchid. In this case, our approach is to use a combination of integrated trend analysis and nonintegrated trend analysis. In the matrix model we will approximate transition probabilities for those stages which are unknown based on information from laboratory experiments or from similar species, such as the western prairie fringed orchid (Armstrong *et al*. 1997). However, since the matrix model may be unreliable, we will also separately analyze annual flowering plant census data for this species.

<u>Factor resolution</u>

Maintaining viable populations of endangered and threatened species requires knowledge of biological and ecological factors contributing to their rarity as well as an understanding of where critical links occur in a species' life history. Factor resolution experimentally analyzes these causes of variation in critical life-history stages identified by trend analysis to have the greatest effect on population growth (Pavlik 1994, Schemske *et al*. 1994).

Factor resolution also includes use of elasticity analysis of matrix models to determine which life history stages contribute most to the calculated population growth rate (De Kroon *et al.* 1986). Elasticties represent the contribution of each element of the transition matrix to finite growth rate (λ). Changes in transition frequencies for matrix elements with large elasticity values will have a relatively large impact on the growth rate. Demographic matrix models can also be used to estimate minimum viable population sizes for long-term sustainability (Menges 1986, 1997) and to project the outcome of alternative management scenarios. For example Menges and Quintana-Ascencio (1998) predicted extinction probabilities, in terms of the chance of extinction in 100 years, and determined the effects of prescribed burning for *Lespedeza leptostachya*, Prairie Bush Clover. Extinction probabilities will be considered in determining the number of viable populations required for a status change (see PVI).

Returning to the Savanna Blazingstar example, because trend analysis indicated potential population decline for Savanna Blazingstar growing in dense Big Bluestem stands, we used factor resolution to determine which life history stages are most vulnerable to an increase in Big Bluestem density and the cause(s) of Savanna Blazingstar reduction in Big Bluestem stands. Recruitment appears to be a critical link in the life history of Savanna Blazingstar since seedling density is significantly lower in dense Big Bluestem stands despite the lower percentage of seed predation (Table 4). In order to determine which stage is most important, experiments are needed to determine whether seed germination or seedling establishment differs in dense and low cover Big Bluestem sites.

Survivorship of Savanna Blazingstar flowering plants was also significantly lower in dense bluestem plots (Table 2) apparently because of small mammal predation. Overall flowering plant predation was not significantly different in low versus dense bluestem sites. However, the type of predation was different. In low bluestem sites, a significantly greater number of flowering stalks were cut off, possibly by meadow voles (*Microtus pennsylvanicus*), preventing successful seed set. In dense bluestem sites, significantly more corms (perenniating organs) were eaten by small mammals causing death of the plant. Thus, small mammal predation has the potential to limit the population size of Savanna Blazingstar differently in different habitats.

Population viability index

For species where data are applicable, we developed a Population Viability Index (PVI) that integrates demographic, biotic and abiotic factors that affect the ability for a population to persist in a given habitat. This index was developed in federal recovery planing for *Dalea foliosa* (DeMauro & Bowles 1994) and *Platanthera leucophaea* (Bowles *et al*. 1992). It combines numerical ratings on factors that critically affect population persistence, such as population growth rates (or non-integrated estimates), population size, habitat size, habitat qualitiy, habitat protection status, and habitat management needs (Table 5).

The Population Viability Index (PVI) is adaptable to meet different biological and ecological features of each species. In a general model, PVI = [A + B + C + D + E + F]/18. Factors A-F represent population growth rates, population size, habitat size, habitat qualtiy, habitat protection status, and habitat management needs, respectively. Assigned values range from 0-3, with a maximum sum of 18. Dividing by 18 scales the index range from 0.0-1.0. Low PVI values are <0.5, moderate PVI values range from 0.5-0.75, and high PVI values are >0.75. In most cases, management, protection, or restoration measures can be used to increase the value of each variable, resulting in an increased PVI. Thus, reclassification objectives can be achieved. Criteria and values for each variable value are explained in Table 5. If populations are no longer present at a site, the index can still indicate moderate viability, but this would only indicate the potential for a habitat to sustain a population.

Table 5. Determination of Population Viability Index (PVI). PVI = [SUM A + B + C + D + E + F_i]/18; values for A-F = 0-3. PVI ranges from 0-1.0, and is divided into three groups. Low viability = ≤ 0.5; moderate viability = >0.5-≤ 0.75; high viability = >.75.

Variable	(0)	(1)	(2)	(3)
	<------Range of values------>			
A. Population growth rate[1]	absent	declining (λ<1)	stable (λ=1)	increasing (λ>1)
B. Population size[2]	very small or absent	small	medium	large
C. Habitat size[3]	very small	small	medium	large
D. Habitat condition - disturbance and successional stage[4]	very heavily disturbed/early-successional (Grade D)	heavily disturbed/early-successional (Grade C)	moderatly disturbed/mid-successional (Grade B)	lightly-disturbed/late-successional (Grade A)
E. Protection status[5]	none	informal	formal	legal
F. Management condition[6]	severe	moderate	low	none

[1] Growth rate is based on demographic analysis of each population, and is expressed as lambda (λ), or a non-integrated alternative. Declining populations (λ<1) are the lowest class, stable populations (λ=1) are intermediate, and increasing populations (λ>1) are the highest class.

[2] Size is based on a mean of annual census data. When only flowering plant census data are used, this may represent <100% of total populations and more closely approximate effective population size (N_e). Values of 0 are given to apparently extirpated populations or small populations that appear in jeopardy or have not been relocated.

[3] Size of habitat represents potential habitat, and may represent a portion of a larger natural area.

[4] Condition based on natural quality (White 1978). In some cases, larger populations may occupy disturbed habitat, but they would be vulnerable to successional change and may not be maintained at high levels without recurring disturbance.

[5] Status is a function of ownership and deed restrictions (Pearsal 1984). None = private ownership with no protection, informal = private ownership without legally binding protection, formal = private or public ownership with formal but not legal protection, legal = private or public ownership with legally binding protection.

[6] Includes degeree of past fire protection and brush invasion for graminoid communities, threats such as exotic species invasion (*e.g.* glossy buckthorn and purple loosestrife), surrounding land use (*e.g.* drainage, development, pollution), and development threats (on private tracts).

RECLASSIFICATION AND RECOVERY STRATEGIES

Modeling recovery: short and long-term goals

Pavlik (1996) sets recovery objectives for rare plants by examining their abundance, extant, persistence, and resilience in a time frame. This model can be used as a framework for setting recovery and de-listing targets, where three threshold stages (endangered, threatened, de-listed) correspond to a time frame evaluated by population performance in relation to life history characteristics (Table 6). In this framework, **endangered species** are at a stage characterized by a minimum population size that allows plants to survive and maintain a founding population without population increase. In this category, perennial plants may persist without reproduction, while annual or short-lived monocarpic species would reproduce and maintain a founding population size. Here, abundance of viable populations is below a threshold for threatened status. **Threatened species** are considered stable on a short-term basis. Here, multiple populations attain a threshold minimum effective population size (Ne) based on a measurable criteria, such as minimum number of genotypes, or attain minimum threshold levels of genetic diversity that characterize plants based on their life-histories (Hamrick & Godt 1989). This stage is characterized by completion of plant species life-cycles and development of multiple cohort structures required to maintain and expand populations. Here, abundance of viable populations is above a threshold for endangered, but below a threshold for delisting. Long-term requirements for **delisting** would include the establishment of a minimum number of viable populations (MVP) throughout a designated range of the species, such as in different Illinois Natural Divisions (see below). Each population should attain a measureable level of viability characterized by a threshold effective population size (Ne), population structure, growth rate, and within-population genetic diversity (G_{ST})

Table 6. Endangered, threatened, and long-term (de-listing) goals and objectives for species recovery.

Goals	Founding Endangered	Short-term Threatened	Long-term Delisting
abundance within populations	1) Minimum number of plants	1) life cycle completed 2) minimum Ne	1) threshold genetic diversity attained
	2) founding plants survive and grow	2) Increased genetic diversity	2) minimum number of viable populations
		3) multiple cohorts present	3) population structure and growth rate
population abundance	1) founding population maintained	1) population expansion occurs	1) historic range restored by natural division
	2) below threshold for threatened	2) above threshold for endangered	2) above threshold for delisting
		2) multiple cohorts develop	2) MVP's attained
resilience/ persistance	1) perennials persist at founding population size	1) expanded populations maintain cohort structure	1) historic G_{ST} attained 2) survive environmental change
	2) annuals maintain founding population size		

Minimum numbers of viable populations

To develop a reclassification and recovery strategy for each species, we assess the biological, ecological, and distributional attributes that affect population viability, and project reclassification criteria based on the number and distribution of viable populations (Table 7). For each species, we recommend numbers of viable populations required for reclassification from Illinois endangered to threatened, and for de-listing. These numbers are based on evaluation of species population viability by the population viability index (PVI). Usually, greater population viability can be achieved by managing to increase population growth rate or size, or improving the management or protection status of occupied habitat. If achievement of highly viable populations (PVI >.75) is not possible due to fixed population/habitat conditions or protection status, a greater number of moderately viable populations (PVI >.50-.75), such as three, can be substituted for each highly viable populations.

For plants occurring in single natural divisions, our general approach is to recommend a minimum of three viable (or nine moderately viable) populations as a requirement for reclassification from endangered to threatened, and a greater number for removal from listing. For plants with ranges extending across different Illinois Natural Divisions and sections, this minimum is increased and balanced among the different different divisions or sections. For example, a species occurring in the Grand Prairie and Northeastern Morainal Natural Divisions might require a minimum of three highly viable populations (or nine moderately viable populations) in each natural division. These requirements can be further divided among different habitats. For example *Platanthera. leucophaea* occupies both prairie and sedge meadow in the Norhteastern Morainal Natural Division. For species restricted to single habitats in one natural division, single metapopulation persistence may be considered as a requirement for reclassification. An example is *Cirsium pitcheri* restoration to unique habitat along the Lake Michigan shoreline.

SUMMARY OF SPECIES VIABILITY AND RECOVERY TARGETS

Viability and recovery targets

Table 7 summarizes the life-history, biological, habitat requirements, and viable populations attributes used to project recovery targets for each species. For most species, this information was combined into a population viability index that was used to set targets for minimum numbers of viable population required for downlisting from endangered to threatened, or for delisting. These targets, research needs, and comparisons with other listed species are summarized in the following paragraphs.

Table 7. Summary of life history, biological, distributional, habitat, and viable population attributes of six Illinois endangered and federal listed plant species.

Species	Life-history/population demography	Genetics/ breeding system	Habitat/ Distribution	Viable population requirements
Asclepias meadii	polycarpic perennial/ limited recruitment with adult longevity & vegetative spread	polymorphic/ self-incompatible bee-pollinated	late-successional prairie formerly widespread/ reduced to 4 populations	high genetic diversity, seedling establishment, & adult persistance/ fire-management
Cirsium pitcheri	monocarpic perennial/ Requires cohort-structured populations	monomorphic/ self-compatible mixed crossing	early successional/ Lake Michigan Dunes/ 1 restored populations	metapopulations with seedling replacement of flowering cohorts
Dalea foliosa	polycarpic perennial with shortlived adults/ seed bank-dependent	monomorphic/ outcrossing required?	late-succesional dry- gravel or dolomite prairie/ 4 extant populations	frequent reproduction/ seed banks/fire-management?

Table 7. Continued.

Hymenoxys acaulis var. *glabra*	polycarpic perennial with vegetative & sexual reproduction	polymorphic/ self-incompatible	late-successional dry-gravel or dolomite priaire 2 restored populations	diversity of SI alleles for sexual reproduction
Lespedeza leptostachya	polycarpic perennial with sexual reproduction, seed bank, & dormancy	monomorphic/ self-compatible mixed crossing	mid-successional dry-mesic gravel prairie 10 populations	disturbance processes, sexual and asexual reproduction/ seed banks
Platanthera leucophaea	polycarpic perennial, short-lived, high levels of recruitment	polymorphic/ self-compatible hawkmoth-pollinated	mid/late-successional formerly widespread 22 populations	minimum population size frequent reproduction, pollinators required

ASCLEPIAS MEADII

____Mead's milkweed is a polycarpic self-incompatible perennial requiring high within-population genetic diversity and virgin prairie conditins (Table 7). It has five native populations, all of which are low viability; four occur in the Shawnee Hills Natural Division, and one in the Grand Prairie (Talbe 8). Six populations have been restored, three in the Northeastern Morainal Natural Division, three in the Grand Prairie, and four supplemental populations have been established in the Shawnee Hills; none of these are high viability. Viability was measured by a population viability index. The species is now endangered. Downlisting to threatened status would require either 21 moderately viable populations or 7 highly viable populations among four natural divisions. Delisting would require 42 moderately or 14 highly viable populations.

The most important research need for this species is cotinued demographic monitoring in relation to prescribed burning managment. This species probably has similar genetic and reproductive requirement of the Illinois listed *A. stenophylla, A. ovalifolia, A. lanuginosa.* For example, the Illinois populations of A. ovalifolia, A. lanuginosa are known to lack seed production and persist vegetatively.

Table 8. Distribution and viability of native, restored, and supplemental(*) Illinois populations of *Asclepias meadii*, and minimum numbers of high or moderate viability population recovery targets for down-listing. Three moderate populations are substitutable for each high viability population. Restored populations in the Shawnee Hills are supplemental to the native populations.

	No.of native Populations			No.of restored Populations			---Minimum No.--- ---for threatened---		---Minimum No.--- ----for de-listing----	
	----Viability----			----Viability----						
Natural Division & Section	High	Mod	Low	High	Mod	Low	Moderately viable	Highly viable	Moderately viable	Highly viable
Northeastern Morainal										
Morainal	0	0	0	0	1	2	3	1	6	2
Grand Prairie										
Grand Prairie	0	0	1	0	2	0	3	1	6	2
Springfield	0	0	0	0	0	0	3	1	6	2
Western	0	0	0	0	1	0	3	1	6	2
Western Forest-Prairie Border										
Galesburg	0	0	0	0	0	0	3	1	6	2
Carlinville	0	0	0	0	0	0	3	1	6	2
Shawnee Hills										
Greater Shawnee Hills	0	0	4	0	0	(4*)	3	1	6	2
Total	0	0	5	0	4	2(4*)	21	7	42	14

CIRSIUM PITCHERI

Pitcher's thistle is a monocarpic perennial that requires new seedling cohorts to replace adults, early successional habitat, and metapopulation function (Table 7). It has one Illinois population, which is under restoration at Illinois Beach Nature Preserve. The species is now listed as Illinois threatened due to its federal threatened status; however, the restored population currently has a negative population growth rate and low viability, and should be listed as endangered. Downlisting to threatened would require positive population growth in two subpopulations, each with >100 plants and a >1 juvenile:adult ratio (Table 9). Delisting would require three or more populations with postive growth rates, each with >200 plants and a >1 juvenile:adult ratio, and functioning as metapopulations.

The most important research need for this species is continued demographic monitoring and genetic studies of differences in performance among seed sources used for its restoration. This species has reproductive and demographic characteristics that may be similar to those of *Lactuca hirsuta* and *Trifolium reflexum*, which occur in prairie. Illinois listed species that occupy similar habitats include the beach zone annuals *Chamaesyce polygonifolia* and *Cakile edentula* and the rhizomatous perennial *Lathyrus maritimus*. Understanding management needs of *C. pitcheri* may contribute to management of these species.

Table 9. Immediate, short-term, and long-term recovery stages for *Cirsium pitcheri*.

Goals	Founding (endangered)	Short-term (threatened)	Long-term (delisting)
Within population abundance	1) 100 plants among two population units	1) positive population growth through sexual reproduction	1) positive population growth through sexual reproduction
	2) founding plants survive and grow	2) >100 plants in two population units	2) three population units each with >200 plants/ha
		3) multiple cohorts present with >1 juvenile:adult ratio	3) multiple cohorts present with juvenile:adult ratio >1
Among population abundance	1) founding population maintained	1) populations north and south of Dead River	1) ≥3 viable populations restored at Illinois Beach
Population resilience/ persistence	1) maintain founding population size	1) expanding populations maintain cohort structure >1 juvenile:adult ratio	1) metapopulation function with multiple populations

DALEA FOLIOSA

Leafy prairie clover is a short-lived polycarpic perennial of dolomite prairies, with low genetic diversity and apparently high dependence on soil seed banks (Table 7). It has four native populations located in the Northeastern Morainal and Grand Prairie Natural Divisions, only one of which is highly viable. The species is now endangered. Downlisting to threatened would require nine moderately and 3 highly viable populations in two natural divisions. De-listing would require 15 moderately and 5 highly viable populations in two natural divisions (Table 10).

The most important research needs for this species include an understanding of its breeding system, reaction to fire-management, role of soil seed banks, and demographic monitoring of a larger number of populations. It shares some characteristics with the other Illinois listed prairie legumes *Lespedeza* *leptostachya* and *Astragalus tennesseensis*. Both species appear to have low genetic diversity and probably rely on soil seed banks for recruitment during years of low seed reprodtuction. However, *Lespedeza leptostachya* has cliestogamous flowers and does not require pollination. The breeding system of *Astragalus tennesseensis* is not understood..

Table 10. Distribution and viability of native *Dalea foliosa* clover populations and minimum numbers of high or moderate viability recovery targets for downlisting. Three moderate populations are substitutable for each high viability population. The Rock River Hill Country natural division is not included because of the questionable presence of former native populations.

Natural Division & Section	No. of native populations ---------Viability---------- High	Mod	Low	Minimum No. for ------Threatened------- Moderately viable	Highly viable	Minimum No. for -------De-listing-------- Moderately viable	Highly viable
Morainal							
Morainal Section	1	1	1	6	2	9	3
Grand Prairie							
Grand Prairie Section	0	1	0	3	1	6	2
Total	1	2	1	9	3	15	5

LESPEDEZA LEPTOSTACHYA

Prairie bush clover is a polycarpic perennial with low genetic diversity, which occupies disturbance patches in dry priaires (Table 7). It has 10 native populations, 8 of which are in the Northeastern Morainal Natural Division; it appears to be declining, but population may fluctuate with rainfall. The species is now endangered. Downlisting to threatened would require 12 moderately and 4 highly viable populations in two natural divisions. De-listing would require 24 moderately and 8 highly viable populations in two natural divisions (Table 11).

Important research needs for this species include continued demographic monitoring and integration with genetic and ecological analysis of Illinois populations. A critical need is to determine factors that affect the success of restored populations. It shares some characteristics with the other Illinois listed prairie legumes *Dalea foliosa* and *Astragalus tennesseensis*. Both species appear to have low genetic diversity and probably rely on soil seed banks for recruitment during years of low seed reprodtuction. However, *t*he breeding systems of of *Dalea foliosa* and *Astragalus tennesseensis* are not understood.

Table 11. Numbers of extant populations, and numbers of moderately viable or highly viable *Lespedeza leptostachya* populations required by Natural Division for down-listing from endangered to threatened or for delisting. The single Oregon Section population includes nine subpopulations.

Natural Division & Section	No. of extant populations	Minimum No. for ------Threatened------- Moderately viable	Highly viable	Minimum No. for -------De-listed-------- Moderately viable	Highly viable
Northeastern Morainal					
Morainal	3	3	1	6	2
Winnebago Dirft	5	3	1	6	2
Rock River Hill Country					
Freeport Section	1	3	1	6	2
Oregon Section	1	3	1	6	2
TOTAL	10	12	4	24	8

PLATANTHERA LEUCOPHAEA

The eastern prairie fringed orchid is a short-lived polycarpic perennial that requires pollination by hawkmoths, soil mycorrhizae, and high levels of seedling recruitment (Table 7). It has 22 native populations in the Northeastern Morainal and Grand Prairie Natural Divisions; only one is highly viable, and the species is listed as endangered. Downlisting to threatened would require 24 moderately or 8 highly viable populations in two Natural Divisions, while delisitng would require 30 moderately or 10 highly viable populations (Table 12).

Important research needs for *Platanthera leucophaea* are demographic monitoring and geneitc analysis of small populaitons to better assess their viability. Laboratory studies are also needed to identify factors affecting seed germination and seedling establishment, and whether such propagation can contribute to restoration of new populations. This species appears similar to two other Illinois listed orchids, *P. ciliaris* and *P. psycodes*. These species also appear to be short-lived orchid and may have similar preproductive requirements and demographic characterists.

Table 12. Distribution and viability of native *Platantera leucophaea* populations and minimum numbers of high or moderate viability recovery targets for downlisting from endangered to threatened (T), or for removal from lising as endangered or threatened (R). Three moderate populations are substitutable for each high viable population.

Natural Division & Section	No. of native populations ---------Viability---------- High	Mod	Low	Minimum No. for ------Threatened------- Moderately viable	Highly viable	Minimum No. for -------De-listing-------- Moderately viable	Highly viable
Morainal							
Lake Michigan Dunes	0	1*	0	3	1	3	1
Chicago Lake Plain	0	0	1	3	1	3	1
Morainal	1	3	12	6	2	12	4
Grand Prairie							
Grand Prairie	0	3	0	9	3	9	3
Western	0	1	0	3	1	3	1
Total	1	8	13	24	8	30	10

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